CHAPTER 5 – SOILS INVESTIGATIONS

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CHAPTER 5 – SOILS INVESTIGATIONS

5.1 GENERAL

5.1.1 General Requirements

Three categories of testing and reports are required for all projects requiring right-of-way grading and paving; geotechnical report, final pavement design (refer to **Chapter 10, Pavement Design and Report**) report, and extra testing (e.g., imported fill).

A. Geotechnical Report.

This report evaluates the characteristics of the soils and the general issues of groundwater, soil stability, and swell potential. If groundwater is found within certain parameters, a subsurface water investigation is required. A geotechnical report is required for street and related improvements within the right-of-way, public easements, or slope easements. This report is required as part of the preliminary plat submittal.

B. Final Pavement Design Report.

This report is required for all projects with public roadway improvements. The soil investigation associated with this report will occur after grading for roadways and utilities is complete. This report must be submitted and approved prior to any nonstructural concrete or paving installation (refer to **Chapter 10, Pavement Design and Report**).

C. Extra Testing.

If fill material is required for the project, this material shall also be tested before placement.

D. Supervision by Engineer.

All sampling and testing of soils shall be performed under the direct supervision of a Professional Engineer who must sign and stamp the report.

5.2 SOIL TESTING FOR GEOTECHNICAL REPORT

5.2.1 Timing of Soil Borings

A. Initial Borings.

The information from the initial soil borings must be summarized in the geotechnical report. The entire site shall be sampled for initial testing. This is required because street locations may not yet be determined or may change.

B. Structures.

Soil borings for design of structures shall be taken prior to the design of the structure.

C. Imported Fill for Right-of-Way Grading.

All fill material shall be tested by the Developer and approved by the Local Entity prior to its use on the project. The material should meet minimum requirements and be equal to or better than existing conditions. No material shall be imported which has a liquid limit greater than 40 and plasticity index greater than 20[MU1][SK2] unless otherwise approved by the Local Entity.

5.2.2 Frequency of Testing

A. Basic Requirements.

A minimum of two borings shall be provided for each project. The number of borings should be dependent on project size and geotechnical Engineer's recommendations. The Local Entity Engineer may require more frequent testing.

B. Structures. [MU3][SK4]

Testing frequency for structures shall satisfy **AASHTO Bridge Design** requirements and **CDOT Materials Testing** requirements.

5.2.3 Location of Samples

A. Basic Requirements.

Samples shall be taken to a minimum depth of 10 feet below the finished grades.

B. Groundwater or Bedrock.

Borings shall extend deeper if needed to determine if bedrock or high groundwater levels are design concerns. Minimum depth to bedrock shall be three feet below the finished subgrade surface.

C. Number of Samples.

Use standard care in determining the number of samples that are needed to characterize soils.

D. Structures.

Samples for structures shall be taken to a minimum depth of 10 feet below the footing elevation. Additional depth may be required for piers or piles.

5.3 SOIL GROUPING

5.3.1 General

To simplify subgrade support testing, soil samples may be combined to form soil groups consistent with the **AASHTO**[LS5][JS6][SK7] classification, group index, and location for the area investigated. Groupings shall not mix samples with different **AASHTO** classifications. (For example, soils with swell potential greater than 2 percent may not be grouped).

5.3.2 Composite Samples

A. Composite Samples.

Composite samples may be obtained by mixing portions of each sample within a soil group to provide a uniform sample of the soil group. The composite samples shall be representative of the worst case subgrade soils for the project site unless separate designs are proposed for distinct soil groups and sufficient field sampling is conducted to determine the special limits of each soil unit identified. Composite samples used for Hveem, subgrade strength testing (R-values) shall not be improved in R-value strength by mixing soils with a higher sand content with material of less strength. Appropriateness of the composite sample shall be evaluated through the comparison of soil gradation and Atterberg limits and soil gradations for the site soils as compared with the subject composite sample.

Table 5-1
Required Tests

Test	Geotechnical Report	Final Pavement Design Report
Visual	X	X
Liquid Limit	X	X
Plastic Limit	X	X
Moisture	X	X
Percent Passing 200	X	X
Gradation (Granular Soils)	X	X
AASHTO Classification	X	X
Subgrade Support: R-value		X
~~R-Value~~		~~X~~
Swell Evaluation(Preliminary Considerations)	Indicator: Low/Moderate/High For Moderate or High, Run Swell Tests	Mitigation and Detailed Analysis
Percentage of Soluble Sulfates	X	X
Standard Penetration Test	X	X
Groundwater	X	X
Bedrock Level	X	X
Corrosion Potential Resistivity	X	

B. Specific Tests for Composite Samples.

Composite samples shall be classified using the methods described in **Section 5.4.2**. Composite samples remolded in the laboratory shall not be used for swell/consolidation testing.

C. Soluble Sulfate Test.

A minimum of one soluble sulfate test shall be run on each composite sample.

5.4 TESTING

5.4.1 Required Tests

The tests marked with an "X" in Error! Reference source not found.~~Error! Reference source not found.~~[MR8][JS9] are required for the subgrade soils investigations or final pavement design testing. Refer to **Chapter 10, Pavement Design and Report** for Final Pavement Design.

5.4.2 Classification Testing

Soils shall be classified visually and tested to determine the properties listed in **Section 5.5**. Sands and gravel samples shall be analyzed for gradation where needed to comply with classification requirements.

5.4.3 Subgrade Support Testing

Individual subgrade or composite samples shall be tested for subgrade support value. The geotechnical report shall clearly state whether or not the subgrade soil is capable of supporting the proposed construction and design traffic loads. ~~In Loveland, t~~T[MU10][SK11]he top foot of subgrade shall have an R-value of 20 or greater. Recommendation for subgrade stabilization, if required, shall also be provided. The final pavement report shall contain specific mitigation. Refer to **Chapter 10, Pavement Design and Report**, for requirements.

5.4.4 Right-of-Way Fill Material Testing

A. Test Prior to Use.

All imported fill material shall be evaluated for swell and R-value and approved by the Local Entity Engineer prior to use in the right-of-way.

B. R-value and Plasticity Index.

All imported fill shall have an R-value and plasticity index equal to or better than the subgrade material within the right-of-way.

C. Expansion Potential.

Imported fill shall not have a liquid limit greater than 40 and plasticity index greater than 20.

5.5 GEOTECHNICAL REPORT

5.5.1 Basic Report Requirements

A geotechnical report shall be submitted with ~~the preliminary plat~~Public Improvement Construction Plans[SK12]. The report shall show results from all required testing in **Table 5-1**. The report shall also include a description of site characteristics, e.g., topography, drainage features, etc.

5.5.2 Detailed Report Requirements

In addition to the basic report requirements, each soils report shall include the following items (refer to **Chapter 10, Pavement Design and Report**, for pavement design report requirements).

A. List of Required Items

1. Site location and description
2. Laboratory test reports with evaluations (classification tests)
    a. Visual classification
    b. Liquid limit - AASHTO T89 or ASTM D4318
    c. Plastic limit - AASHTO T90 or ASTM D4318
    d. In-situ moisture content
    e. Percent passing No. 200 sieve - AASHTO T11 or ASTM C117-90
    f. Gradation of granular (sand & gravel) materials - AASHTO T27, ASTM D422 or ASTM C136
    g. AASHTO classification and group index - AASHTO M145
    h. Standard Penetrations Test
    i. Swell Evaluation
3. Boring logs
4. Soil and groundwater conditions. The expected seasonal elevation variation shall be summarized.
5. Depth to bedrock. To indicate shallow bedrock. Include mitigation requirements if bedrock is within 3 feet of subgrade.
6. Percentage of soluble sulfates.

7. Recommendations and discussions
8. Mitigation plans
9. Additional tests. These may be required for trench backfill evaluation, fill evaluation, etc.
10. Elevation of groundwater encountered in each boring
11. Engineer seal and signature. Required.

5.6 SUBSURFACE WATER INVESTIGATION

5.6.1 When a Subsurface Water Investigation Is Required

A. Criteria.

If groundwater or bedrock is encountered or predicted to be encountered within 5 feet of the original or proposed ground surface, a subsurface water investigation report shall be submitted for approval by the Local Entity Engineer. This report is required to ensure mitigation of high groundwater effects upon public improvements within the right-of-way. This information may be a separate report or may be included in the geotechnical report.

B. Requirement Waiver[JB13][JS14][SK15]**.**

This report requirement may be waived if the Applicant and Designer certify that the street subgrade elevations will be a minimum of 3 feet above the "maximum" predicted (seasonal highest) water table. The requested waiver shall signed and stamped by a Professional Engineer.

C. Exception for Buried Utility Construction.

This report is not required for temporary dewatering activity needed to facilitate construction of buried utilities. However, all applicable state requirements must be followed.

5.6.2 Report Requirements

The subsurface water investigation report shall include the following information.

A. List of Required Information

1. Site location and description. Include locations of any irrigation ditches and wetlands.
2. Elevation of water table, direction of flow, flow rates, groundwater barriers, and seasonal high water level.
3. Potential sources of groundwater. Include proximity to irrigation ditch systems ~~or proposed low impact development systems~~.

4. Water rights.
5. Other relevant subsurface information such as water ownership (water rights), groundwater quality (contamination or other undesirable characteristics).
6. Potential future groundwater conditions[SK16].
7. Subsurface drainage recommendations, including its effects on all conditions, including sensitive habitat.
8. Cone of influence.
9. Control measures and designs.
    a. Subsurface Drains. If subsurface drains are recommended, the drains must have a gravity discharge without any possibility of back flow or blockage of the outlet. Any subsurface drain system shall be owned and maintained by the Developer or the Developer's assigned successor(s). These drains may discharge into the Local Entity's storm drainage system, including inlets or detention ponds, upon approval of the Local Entity Engineer. The underdrains may not drain to the gutter/flowline of public streets. Anticipated impacts to the groundwater table on adjacent properties must be quantified. The plat and construction plans shall clearly state that the City—/—County has no maintenance responsibility for this utility and any damage caused by said maintenance shall be repaired by the entity in charge of maintenance to pre-existing conditions or better.
    b. Drain Lines. The drain lines may be installed in the sanitary sewer trench, at an elevation of one sewer diameter lower than the sanitary sewer line, except in Loveland (city limits only[SK17]). Refer to the section/subsection titled **Drainage Systems – Subdrains** in **Chapter 7** for location in Loveland (city limits only). Flexible pipe will not be accepted.
    c. Drain Line Separation from Sewer. The drain line shall be marked to specifically distinguish the drain from the sanitary sewer line.
    d. Pipe. The drain line shall be an approved material pipe, for long-term 100 years minimum design life, with appropriate cleanouts.
    e. Drain Outlet. The outlet of the drain into an inlet structure or detention pond shall be designed to prevent any possibility of backflow and blockage of the drain line.
10. Professional Engineer's seal and signature.

5.7 SOIL PROBLEM MITIGATION

Mitigation plans for soil problems revealed by the soils investigation shall be submitted to the Local Entity Engineer. The following specific factors shall be addressed:

5.7.1 Mitigation Plans and Approval

All special problems found in soils investigation (e.g., expansion, frost, soluble sulfates, shallow bedrock, heave, groundwater, soil instability, utility backfill, etc.) shall be addressed in the mitigation plans. All mitigation procedures must be approved by the Local Entity Engineer prior to their implementation.

5.7.2 Mitigation for Swell

If the swell of any subgrade soils is 2.0 percent or greater, the pavement design report must provide mitigation measures for said soils. Soil swell testing shall be conducted with soil samples that have an initial moisture content equal to or less than 4 points below optimum moisture for said material. The mitigation measures shall reduce destructive swell potential under the public improvements, including landscaping, to an acceptable level of less than 2.0 percent at 150 psf surcharge. The swell test report shall specify sample conditions, surcharge pressures, and other key testing factors.

5.7.3 Swell Mitigation Measures[JB18][JS19][JS20][SK21]

Possible measures for mitigation may include the following:

A. Over-Excavation.

Over-excavation and replacement with suitable non-expansive or low-expansive material to a depth sufficient to mitigate expansion is a common mitigation method.

B. Chemical Treatment.

Chemical treatment may be used to mitigate expansive characteristics of the soil.

C. Subdrains.

Subdrains may be effective at reducing the groundwater, thereby reducing swelling. However, subdrains will be subject to all of the subsurface drain requirements in these Standards.

D. Moisture Treatments.

Condition with moisture and compact to an appropriate level of compaction for the expansive condition, including stability requirements. The geotechnical engineer shall specify the target moisture content based on laboratory testing. Moisture content of the prepared subgrade soils shall be tested within 24-hours prior to paving. If unstable paving conditions due to over moistened soils appear, the contractor shall cease paving and the geotechnical engineer shall develop other forms of mitigation.

E. Other Procedures.

Other procedures may be proposed for review and approval by the Local Entity Engineer. The chosen method must work for the full life expectancy of the improvements.

5.7.4 Mitigation of Unstable Subgrade (Examples)

A. Over-Excavation.

Over-excavation and replacement with suitable non-expansive material to a depth sufficient to stabilize the subgrade is a common mitigation method.

B. Chemical Treatment.

Chemical treatment to eliminate unstable characteristics of the soil is another common mitigation method.

C. Other Procedures.

Other procedures may be proposed for review and approval by the Local Entity Engineer.

5.7.5 Specific Mitigation Requirements

A. Extent of Mitigation.

Moisture treatment alone may not be sufficient. If soil problem mitigation is made, the soil treatment shall extend to the back of curb, or to the back of walk for attached or monolithic walk. For detached walk, separate mitigation procedures may be required.

B. Approval of Chemical Treatment.

Mitigation procedures that alter existing soil conditions (such as lime, fly ash, or cement treatment) shall follow an approved mix design process. Additional testing is required to verify that no swell is introduced in the chemical treatment.